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EFFECT OF SEEPAGE FLOW ON REED CANARYGRASS AND ITS ABILITY TO PROTECT WATERWAYS

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UNITED STATES DEPARTMENT OF AGRICULTURE
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EFFECT OF SEEPAGE FLOW ON REED CANARYGRASS AND ITS ABILITY TO PROTECT WATERWAYS

By W. O. Ree[1]

ABSTRACT

Reed canarygrass, a water-tolerant grass, was planted in an existing bermudagrass cover in an experimental channel to determine if a long-duration small (seepage) flow would adversely affect the mixture of dry-land and water-tolerant grass species and lessen its ability to protect the waterway. Simulated flood flows following 72 days of seepage flow (about 1.3 inches deep) did not damage the waterway. During the 72-day continuous small flow the reed canarygrass developed a great mass of adventitious roots at the channel surface. Similar roots developed on the bermudagrass but to a much smaller extent. The root mass provided protection against erosion by the deeper, swifter flood flows. The stand density of the bermudagrass was adversely affected by the long-duration flow. Tests the following year with an intermittent seepage flow (5 days on and 10 days off for three full cycles), before the flood-flow tests, were inconclusive. No new adventitious roots developed, but those from the previous year were still there for channel protection. The intermittent flow increased the stand density and stem length of the bermudagrass.

KEYWORDS: grassed-waterway protection, long-duration small flow, reed canarygrass, stand density and stem length, surface-root mass.

INTRODUCTION

Grass waterways safely convey storm runoff from sloping fields because the grass protects the waterways from erosion by the deep, swiftly moving flows. In this role the grass can be likened to a structural material that lines and protects the waterway. The best grass for this purpose is a dense sod, and sod-forming grasses normally thrive on dry land rather than in swamps. Since storm runoff does not last long and temporary submergence does not harm the grass, dryland grasses can be used for waterway protection. However, some grass waterways may at times convey long-duration small flows originating from seepage or, in some instances, from irrigation tailwater. Will a long-duration small flow damage the grass and lessen its ability to protect the waterway? Will a mixture of dryland and water-tolerant grass species maintain or enhance the protective ability of the cover under prolonged wetting? The answers to these questions were sought in the experiment described in this report.

Small clumps of reed canarygrass (*Phalaris arundinacea*) were transplanted into the existing bermudagrass cover in the center part of a V-shaped experimental waterway at the Water Conservation Structures Laboratory. The waterway was then subjected to a long-duration small (seepage) flow. Following this simulated seepage flow, large flows were turned into the waterway to simulate several flood-flow rates. The performance of the waterway was observed, with particular attention given to the effect on the quality of the grass cover and its

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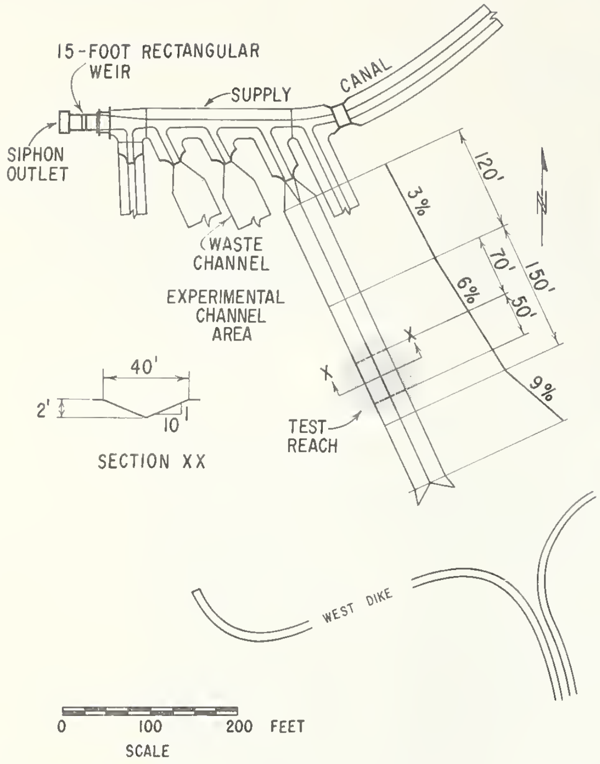

FIGURE 1.—Test channel showing location of test reach.

ability to protect the waterway from scour. The experiment was conducted over a 2-year period with a different initial seepage-flow schedule each year. The tests for each year are described separately.

TEST CHANNEL

A bermudagrass-lined channel was selected for the experiment. This channel is 329 ft long by 40 ft wide by 2 ft deep and is of triangular cross section. The bottom slopes are 3 percent for the upper 120 ft and 6 percent for the lower 150 ft (fig. 1). Previous flow tests on the channel determined the permissible velocities for the bermudagrass for different seasons and for various lengths of mowing. The data from these earlier tests served as a base for comparison with the results of tests reported herein.

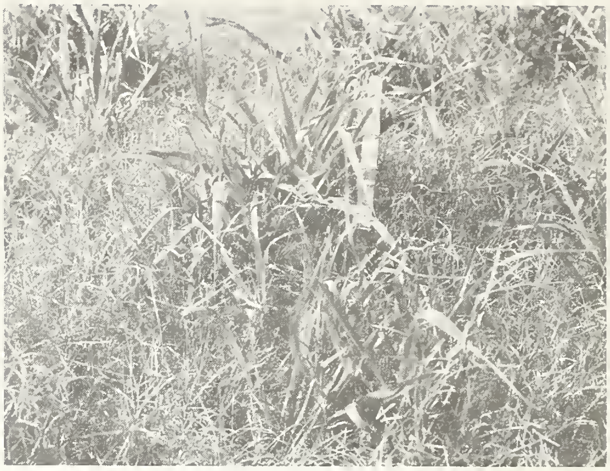

FIGURE 2.—Closeup view of grass in test reach. (Reed canarygrass is the broad-leaved grass.)

In mid-August clumps of reed canarygrass were planted in a 3.5-ft-wide strip down the center of the channel in the 6-percent-slope reach. The clumps of grass were planted about 1 ft apart in the existing bermudagrass cover and were randomly placed to avoid formation of lengthwise rows. Immediately after the planting a flow of 0.065 ft^3/s was turned into the channel and allowed to run continuously for 72 days. This flow had a center depth of about 0.11 ft and spread to a width of about 8 ft. The center depth was much less than would ordinarily be calculated from the flow top width and the 10-to-1 side slopes of the channel. The reason for the smaller than normal depth is the rounding of the V in the channel center during construction and planting.

FIRST-YEAR TESTS AND RESULTS

The large-flow tests were begun early in November, 72 days after planting the reed canarygrass and starting the seepage flow (test 1). The grasses in the wetted (center) portion of the channel, both the bermudagrass and the reed canarygrass, were a bright green. Both grasses thrived and grew under the continuous wetting, but the grass outside the wetted area was brown and stunted because of the dry

TABLE 1.—*Density and length of grass stems in channel just before large flows in first-year experiment*

Vegetation	Density (stems/ft²)	Length (in)
Wetted Portion:		
Bermudagrass	100	5.0
Reed canarygrass	60	10.0
Dry Portion:		
Bermudagrass	189	2.6

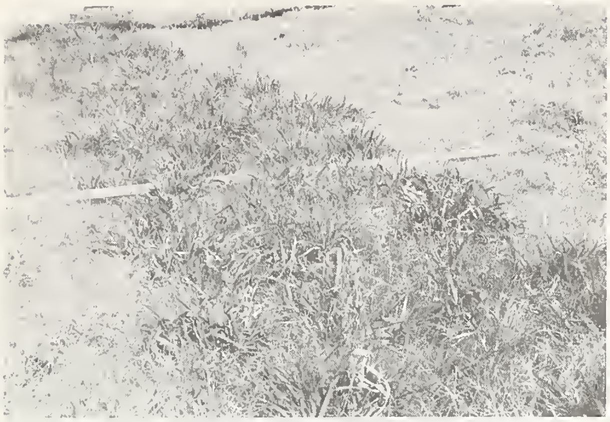

FIGURE 3.—Test reach at start of large-flow tests.

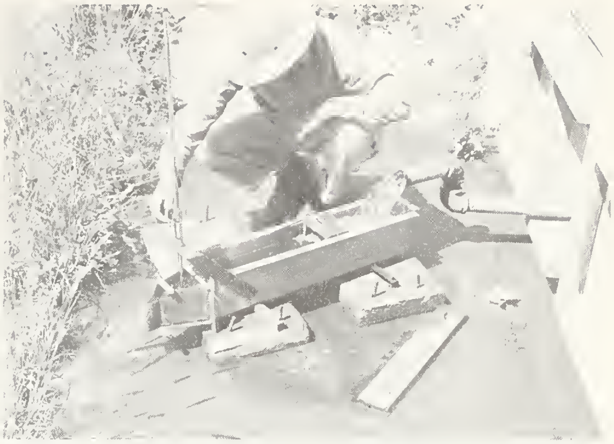

FIGURE 4.—The 0.4-ft H-flume measuring low-flow rate of long-duration flow.

summer weather. The stand count of the vegetation at the start of the tests is given in table 1. Figure 2 is a closeup view of the grass just before the seepage flow was shut off; the grass hides the flow. Figure 3 shows the test reach before the large-flow tests. The dark center strip is the green, well-watered vegetation.

The tests consisted of a succession of 10 flows down the channel, with each flow being larger than the previous one. After each flow the water was turned out, and the channel and grass were examined for signs of erosion or damage. The test schedule is given in table 2.

The smallest flow (test 1) was measured with a 0.4-ft H-flume (fig. 4). The intermediate flows (tests 2 through 4) were measured with a 1.5-ft H-flume temporarily installed in the gate opening at the head of the test channel (fig. 5). The largest flows (tests 5 through 11) were measured with a rectangular, rounded-crest (15-foot) weir at the siphon outlet (fig. 1). For these flows the H-flume was removed from the gate opening, and the hoist gate was operated to start or stop the flow.

TABLE 2.—*Test flows for first-year experiment*

Test No.	Discharge rate (ft^3/s)	Duration[1] (min)
1	0.065	(2)
2	.86	...
3	2.13	...
4	4.58	...
5	9.37	...
6	16.1	40
7	29.8	40
8	49.9	40
9	74.5	40
10	123	40
11	142	40

[1] For tests 2 through 5 erosion was not expected and flow duration was uncontrolled, but it generally lasted about 1 hour.

[2] Seepage flow for 72 days.

The flows for tests 6 through 11 were maintained at a constant rate for 40 minutes, which was accomplished by satisfying the storage requirement of the supply canal and bringing the flow to a steady state in the adjoining waste channel (fig. 1) before instantaneously diverting the flow into the channel. After 40 minutes the flow was abruptly shut off by closing the

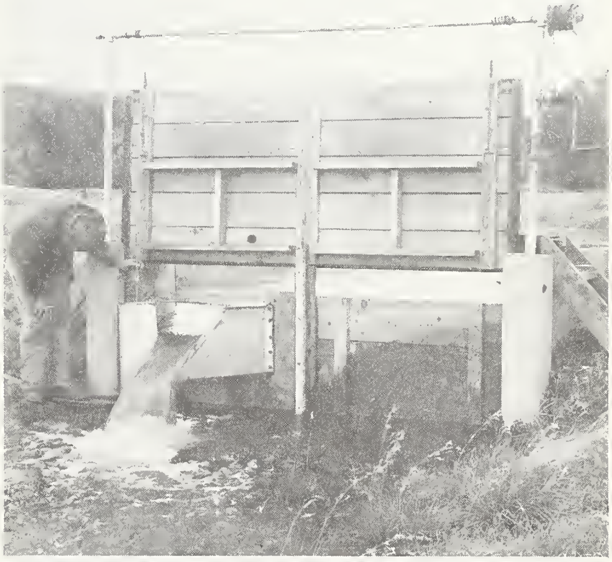

FIGURE 5.—The 1.5-ft H-flume that measured flow rates of 0.86 to 4.58 ft^3/s.

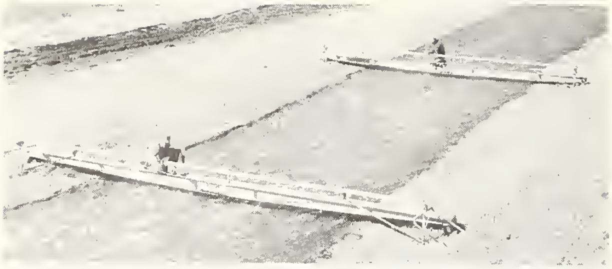

FIGURE 6.—Channel during test 10 with flow of 123 ft^3/s. (Observers are measuring water-surface elevations at upper and lower ends of test reach.)

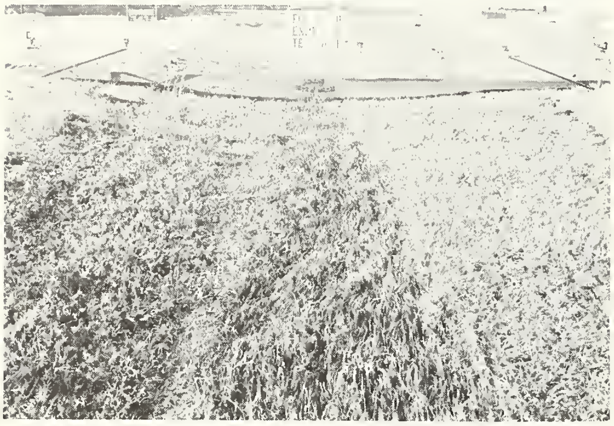

FIGURE 7.—Channel after completion of test flows.

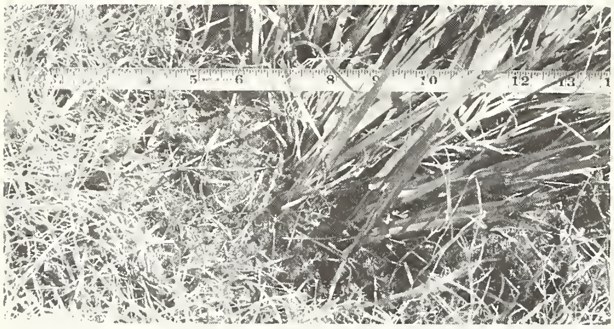

FIGURE 8.—Closeup view of mass of fine, adventitious roots at base of reed canarygrass plant.

gate at the head of the channel and diverting the flow back to the waste channel.

Measurements of the flow cross sections were made at two stations 50 ft apart. Water-surface measurements were made at 1-ft intervals across these stations during each test flow. Bottom elevations were measured at these same stations after tests 1, 2, 6, 7, 8, 9, 10, and 11. Figure 6 shows the observers measuring the water surface during test 10 (flow rate of 123 ft^3/s).

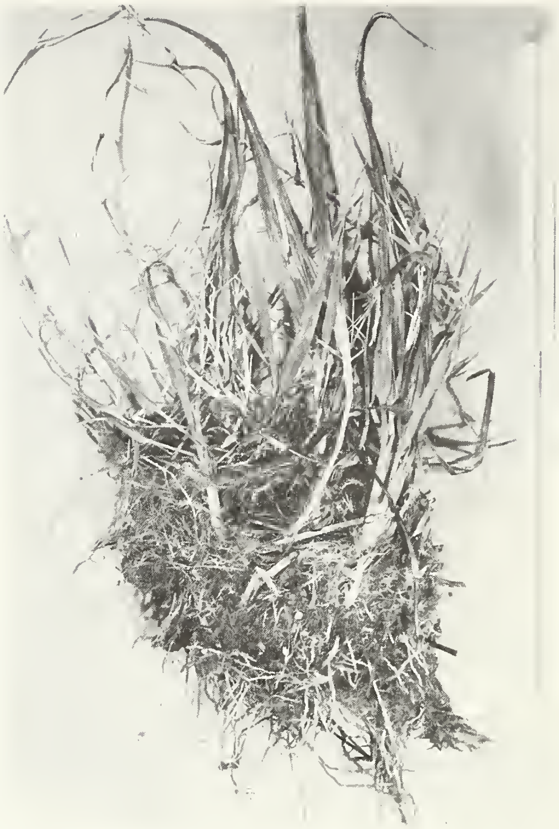

FIGURE 9.—Closeup view of reed canarygrass and bermudagrass plants after flow tests, showing crowns and roots.

The test flows had no visible effect on the channel except for the "scrubbed and combed" appearance of the vegetation (fig. 7). Bottom measurements taken after tests 6 and 11 showed a 0.026-ft erosion depth over a 10-ft-wide center strip. This is an equivalent erosion rate of 0.09 in/h for the 3.3 hours of flow that accumulated during tests 7 through 11. A study by Ree and Palmer[2] showed that not until erosion rates exceed 0.2 in/h does the erosion rate correlate with the mean velocity. Below this rate the indicated erosion rates were not significant. Therefore, the erosion rate of 0.09 in/h was not excessive, and the grass cover adequately protected the channel.

Contrary to expectations, instead of the grass being weakened by the long-duration flow, its ability to protect the channel bed was enhanced. Why did the grass perform so well? The ex-

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[2] Ree, W. O., and Palmer, V. J. 1949. Flow of water in channels protected by vegetative linings. U.S. Dep. Agric. Tech. Bull. No. 967, 115 pp.

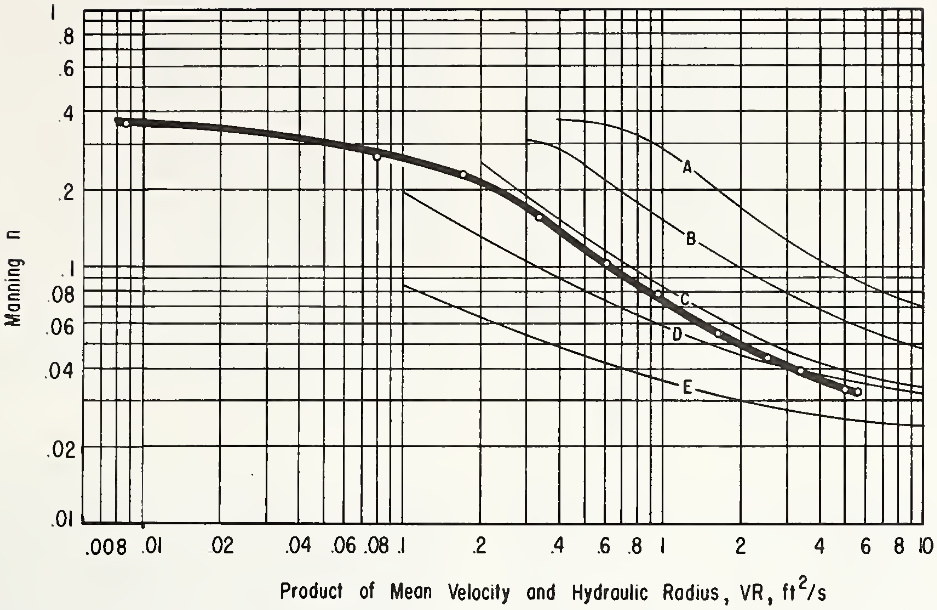

FIGURE 10.—Manning *n* values plotted against corresponding values of *VR* for first-year tests.

planation is in the great mass of roots that developed at the channel surface. Figure 8 shows these adventitious roots at the base of the grass stems. Figure 9 shows a clump of grass from the channel, with its roots washed free of soil. This root density was typical of the roots from the continuously wetted portion of the channel.

The Manning *n* values are plotted against *VR* (product of velocity and hydraulic radius) in figure 10; the relationship is shown by the heavy line. The *n–VR* curves for the standard retardance classes (A to E), as defined by the "Handbook of Channel Design for Soil and Water Conservation,"[3] are shown in the lighter (thin) lines so that the appropriate retardance class for the vegetation in this experiment can be determined by comparison.

The *n–VR* curve for the test vegetation does not follow the standard curve pattern. Instead, at a *VR* value of 0.33 the retardance class was about C, and, as the *VR* value increased, the retardance class gradually dropped to below D at a *VR* value of 3.2. The explanation for this departure of the *n–VR* curve from the standard is found in the variation of grass lengths along the perimeter of the channel. For the smaller *VR* values most of the flow was in the center of the channel. The grass there was lush, and the stem lengths ranged from 5 to 10 inches. According to the handbook (cited in footnote 3) the expected retardance class is C, which was the determined class in this experiment. At a *VR* value of 5.6 the flow had a 25-ft width, and much of the flow was over the shorter grass (2.6 inches), which had a retardance class of E. So the retardance class for this channel could be expected to drop as the flow width increased. The observed retardance between classes D and E at the *VR* value of 5.6 seems reasonable for the existing combination of retardances in the center and at the edges of the channel.

SECOND-YEAR TESTS AND RESULTS

The continuous 72-day small (seepage) flow during the first year caused massive root development at the base of the grass stems, which provided excellent protection to the channel. Would this mat of surface roots have developed if the simulated seepage flow had been intermittent, say coinciding with an irrigation schedule for the fields above? Or would these roots have failed to develop, causing the channel cover to weaken instead? An experiment, using the same channel, was developed

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[3] U.S. Dep. Agric., Soil Conserv. Serv. [Rep.] SCS-TP-61, 34 pp. (1954).

TABLE 3.—*Seepage flows for second-year experiment*

Date	Discharge (ft³/s)	Duration (hours)
June 15–20	0.063	120
July 5–10	.060	120
July 25–30[1]	.056	120

[1] This flow was also flow for test 1.

to answer these questions. No flows were introduced into the channel from November to mid-June, when the second experiment was begun. For this experiment the small (seepage) flow was intermittent, simulating tailwater flow from irrigation, with flow on for 5 days and then off for 10 days. The schedule of seepage flows is given in table 3.

Before the second-year tests began the channel looked about the same as it did the year before (fig. 11). Close inspection of the channel bed showed that the adventitious roots that developed the previous year were still there, though most of them were dead. Figure 12 shows a closeup view of the vegetation, which was measured before and after each flow. Stand counts for the second year are given in table 4. In the wetted portion of the channel the density and stem length of both grass species increased during the intermittent seepage flows. Evidently, the three seepage flows provided good irrigation. The variation in the stand-count and stem-length trends is probably attributable to the random distribution of the cover and to the random selection of count locations. No new adventitious roots developed from the three 5-day flows. The testing technique and the

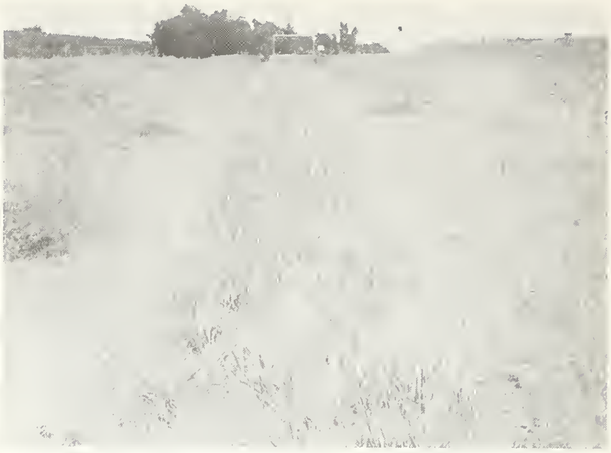

FIGURE 11.—Channel at start of intermittent small flows. (Tall, broad-leaved grass is reed canarygrass.)

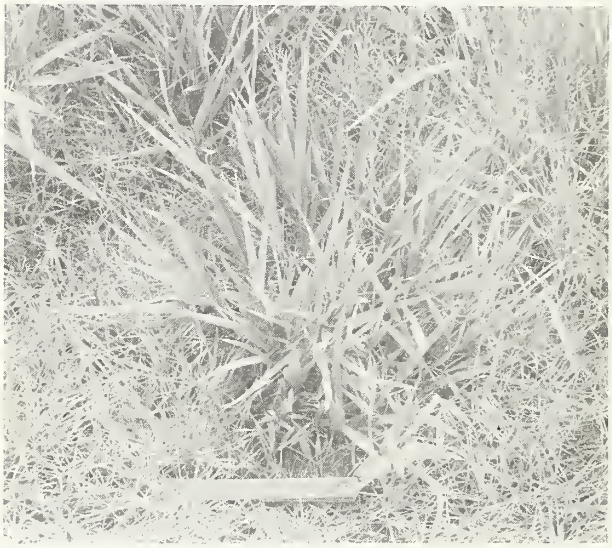

FIGURE 12.—Closeup view of vegetation at start of intermittent small flows. (Broad-leaved grass is reed canarygrass, and fine-leaved grass is bermudagrass.)

TABLE 4.—*Density and length of grass stems in channel during second year*

Date	Bermudagrass[1]		Reed canarygrass[1]		Bermudagrass[2]	
	Density[3] (stems/ft²)	Length (in)	Density (stems/ft²)	Length (in)	Density (stems/ft²)	Length (in)
June 14	[4]155	8.0	29	12	114	2.5
22	151	7.0	36	10	168	4.0
July 3	164	6.5	34	11	150	3.0
12	196	9.0	45	12	160	3.0
24	264	9.0	60	13	174	4.0
Aug. 3	220	11.0	57	15	170	3.0
13	236	14.0	50	17	120	4.0

[1] Stems from wetted portion of channel.
[2] Stems from dry portion of channel.
[3] Stem density between reed canarygrass plants.
[4] Litter and dead adventitious roots at base of stem.

TABLE 5.—*Test flows for second-year experiment*

Test No.	Discharge (ft^3/s)	Duration[1] (min)
1	0.056	([2])
2	.43	...
3	1.09	...
4	2.36	...
5	4.52	...
6	10.0	40
7	20.1	40
8	40.2	40
9	80.0	40
10	108	40
11	120	40

[1] For tests 2 through 5 erosion was not expected and flow duration was uncontrolled.

[2] Seepage flow for 120 hours.

apparatus for these tests were the same as those used for the first-year experiment. The schedule of test flows for the second year is given in table 5.

The test flows did not visibly damage the channel (fig. 13). However, close examination showed erosion upstream of the reed canarygrass (fig. 14). A comparison of the bottom elevations after tests 7 and 11 showed an average erosion depth of 0.004 ft, which is equivalent to a soil removal rate of 0.018 in/h (duration 160 minutes). This rate of soil removal is not significant.

Figure 15 shows the *n–VR* curve for the second-year tests. The plotted points follow the class C retardance for all but the largest *VR* value, where the retardance dropped to class D.

DISCUSSION

The long-duration small flow of approximately 0.06 ft^3/s was wide and shallow, 1.3 inches deep at the most. Grass stems and leaves extended well above the water surface and hid it from view. During the continuous 72-day small flow the bermudagrass and reed canarygrass developed a great mass of adventitious roots at the channel bed. However, the greatest root development was on the reed carnarygrass plants, which had a root mass at least 20 times greater than that on bermudagrass plants of comparable size. The roots of the reed canarygrass were so tough that they could not be pulled out, even though the soil was so soft that a pencil could be pushed full length into it with ease. A spade was needed to get grass samples for inspecting and photographing. This continuous mass of roots formed a protective mat for the channel surface.

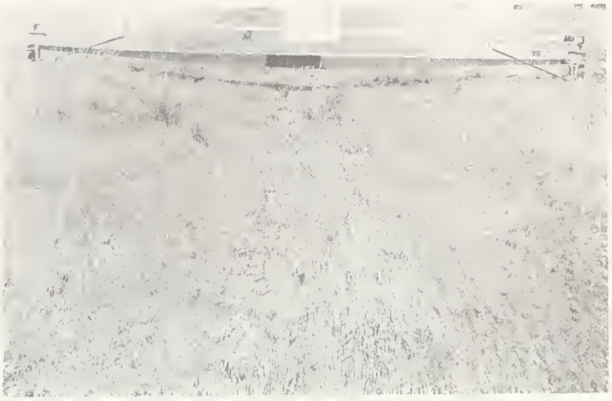

FIGURE 13.—Channel immediately after completion of large-flow tests.

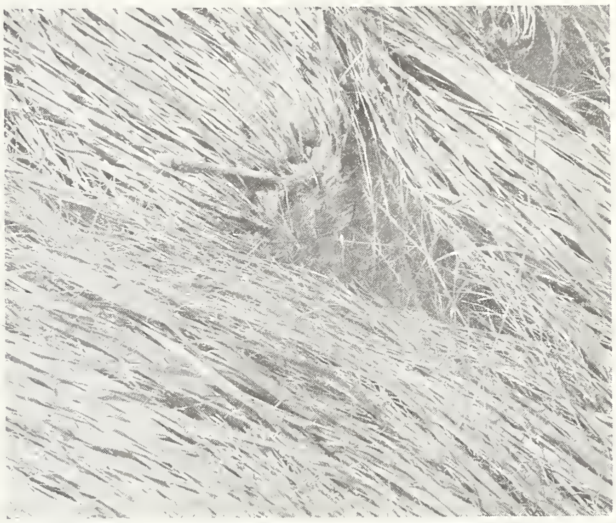

FIGURE 14.—Closeup view of reed canarygrass plant after flow tests, showing erosion at base of plant.

The bermudagrass plant population may have been reduced by the continuous 72-day flow. The stand density was 100 stems/ft^2 in the wetted portion and 189 stems/ft^2 in the parts of the channel not submerged by the small, continuous flow. However, the grass in the wetted part of the channel was still green and pliant, but the grass alongside was relatively short, dry, and brittle. Despite the relatively small total plant population in the center of the channel, the cover provided erosion protection for the channel against flow velocities exceeding 8 ft/s. The mat of roots at the channel surface must be given considerable credit

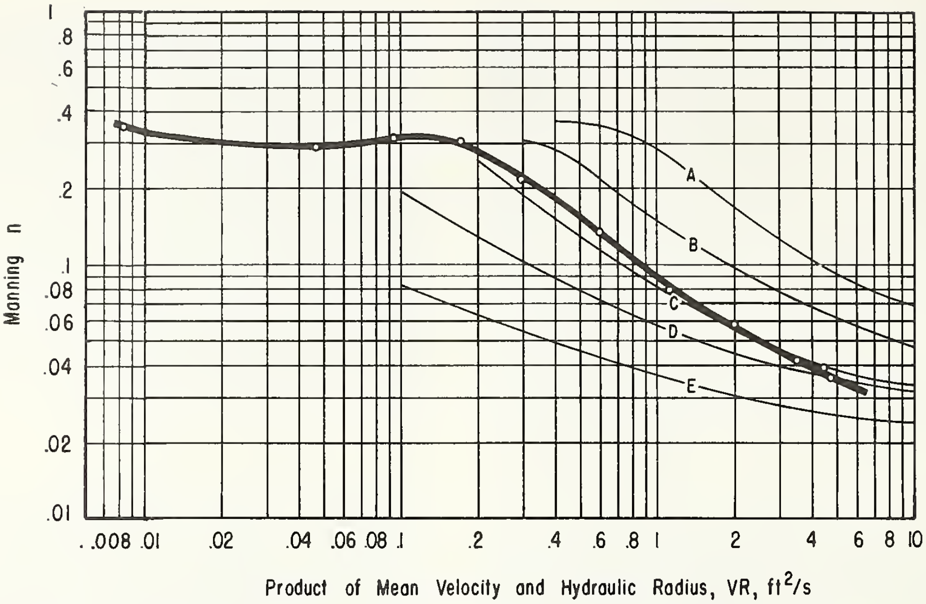

FIGURE 15.—Manning *n* values plotted against corresponding values of *VR* for second-year tests.

for the protective ability of the cover. The long-duration flow did not weaken the cover, but instead strengthened it.

The intermittent small flows of 5 days on and 10 days off for three full cycles did not provide a clear-cut answer to the following question: Did these intermittent flows weaken the protective ability of the grass? The old root mass from the tests the year before was still there, but the root mass and grass stems extending from it were dead. However, the root mass was still anchored to the channel and probably provided some protection against scour damage by large flows. The intermittent flow was not harmful. Instead, the flow was beneficial in that it irrigated the center of the channel. In the center of the channel the bermudagrass density increased from about 150 to about 230 stems/ft^2, and the average stem length increased from 8 to 14 inches. The reed canarygrass suffered some setback during the winter because the stem density dropped from 60 stems/ft^2 during the first-year tests to 29 stems/ft^2 at the beginning of the second-year tests. However, during the intermittent flows the density recovered to over 50 stems/ft^2, and the average stem length increased from 12 to 17 inches.

The second-year cover also provided erosion protection to the channel against a flow velocity exceeding 8 ft/s. Its good protective qualities should be attributed in part to the old root mass as well as to the good stand of grass. Both the continuous and intermittent small flows maintained, if not strengthened, the protective ability of the bermudagrass-reed canarygrass cover.

The *n–VR* curves were distorted in comparison to the normal curves obtained from tests on a uniform-length cover. The taller grass in the channel center determined the curve position for the smaller flows. The shorter grass along the channel sides caused a downward shift of the curve for the larger flows, reflecting a lesser flow resistance.

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